AD-A102 945 WESTON OBSERVATORY MA F/G 20/3

INVESTIGATION OF MAGNETIC FIELD MEASUREMENTS.(U)

MAY 81 J F DEVANE, E A JOHNSON F19628-80-C-0005

UNCLASSIFIED SCIENTIFIC-1 AFGL-TR-81-0135 NL

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INVESTIGATION OF MAGNETIC FIELD MEASUREMENTS

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15 May 1981
Scientific Report No. 1
1 October 1979 - 30 April 1981

Approved for Public Release; Distribution Unlimited.

AIR FORCE GEOPHYSICS LABORATORY
AIR FORCE SYSTEMS COMMAND
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HANSCOM AFB, MASSACHUSETTS 01731

81 8

(14) SCIENTIFIC-1

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: AFGL-TR-81-0135	2. GOVT ACCESSION NO.: AD-A102945
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): INVESTIGATION OF MAGNETIC FIELD MEASUREMENTS	5. TYPE OF REPORT & PERIOD COVERED: Scientific Report No. 1, Oct. 1, 1979-April 30, 1981
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): John F./Devane, Jr., Edward A./Johnson	8. CONTRACT OR GRANT NUMBER(s): F19628-80-C-0005
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Boston College, Weston Observatory, Weston, MA 02193	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 62101F 760108AN
11. CONTROLLING OFFICE NAME AND ADDRESS: Air Force Geophysics Laboratory, Hanscom AFB, Massachusetts 01731, Monitor/Irving Michael, PHG	12. REPORT DATE: May 1981
	13. NUMBER OF PAGES: 18
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): Office of Naval Research, Building 14 Section D 668 Summer St., Boston, MA 02210 Michael H. Kelly	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

AFGL Magnetometer Network, Fluxgate Magnetometer, Induction-Coil Magnetometer, Search-coil Magnetometer, and Microcomputer.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Contractor investigates magnetic field measurements, magnetic field measuring devices and the magnetic properties of materials by operating and maintaining a low-field coil facility and magnetic observatory, by evaluating the accuracy and reliability of the AFGL Magnetometer Network and by improving Network performance through the design, testing and implementation of hardware modifications and/or additions.

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1. INTRODUCTION

The fundamental purpose of this contract is to investigate magnetic field measurements, magnetic field measuring devices and the magnetic properties of materials by operating and maintaining a low-field coil facility and magnetic observatory, by evaluating the accuracy and reliability of the AFGL Magnetometer Network (Ref. 1) and by improving Network performance through the design, testing and implementation of hardware modifications and additions.

2. INSTRUMENTATION

2.1 The Fluxgate Magnetometer.

The reliability of the fluxgate magnetometer was improved substantially by modifying the basic instrument as detailed in a prior report (Ref. 1). Many of the difficulties were due to the digital-to-analog converter (DAC). The original DAC is being replaced by an improved DAC. From the outset, the manufacturer found the magnetometer output to vary slightly with temperature (Ref. 2). This temperature sensitivity is under investigation and will be described later.

2.2 The Induction-Coil Magnetometer.

The induction-coil magnetometer built by Geotronics has been subject to many types of failure, the most serious being its susceptibility to lightning-induced transients. Many improvements have been made to protect the instrument from lightning effects and the details are given in Ref. 3. There were failures due to lightning during the summer of 1980, but fewer than in previous years.

The master oscillator was failure prone and an inexpensive replacement was found to be satisfactory and has been used to replace the master oscillators in all the Geotronics units in the Network.

Since the state-of-the-art in linear integrated circuits and integrated modular assemblies has advanced significantly in recent years, work towards building a replacement for the Geotronics magnetometer has started. The new unit will have improved characteristics such as lower offset drift and lower noise and will be of modular construction allowing easy trouble shooting and repair.

3. ON-SITE ASSISTANCE

In October 1979, a policy was initiated to make use of personnel at the field sites to do routine inspection and to make simple repairs or adjustments. Each station has at least one individual who can make periodic visits to the trailers. Layout drawings of the magnetometers were provided so that simple adjustments and replacements can be made according to instructions telephoned from Weston Observatory or AFGL. This procedure has resulted in a significant saving of travel funds and has reduced the down time of the instruments.

4. THREE-COMPONENT OBSERVATORY DEVELOPMENT

Construction of a three-component magnetic observatory using a Cesium vapor magnetometer and a McKeehan three-axis coil system continues. The vector components of the field can be calculated by sequentially adding magnetic fields caused by known currents in the coils along each axis. Originally, mechanical wipers were used for coil switching, but the contacts eventually deteriorated and became noisy. This problem was eliminated by replacing the wipers with reed relays controlled by a microprocessor. An MEK6800D2 microcomputer development kit was purchased and built for this purpose. The microcomputer

will also be used for data manipulation and control of a paper tape punch. A coil control interface was constructed, and a program was written for the microcomputer. The system was tested and field component values obtained but the results were inconsistent. Close examination of the McKeehan three-axis coil system revealed that at least one wire in the Z-axis coil was shorting to the aluminum coil form and part of the Y-axis coil was shorting internally. The coil system will be repaired and work continued.

5. ANALYSIS OF TEMPERATURE DEPENDENCE OF THE FLUXGATE MAGNETOMETER

A temperature-controlled chamber, 2½ x 2½ x 2½ ft., mounted on casters and lined with three inches of foam insulation, was constructed to test the temperature dependence of the magnetometers and other Network equipment. Initially a fluxgate magnetometer was tested. Temperatures were measured with the internal magnetometer temperature sensor and two additional sensors. The three sensors agreed closely. Tests were performed in the temperature-stabilized observatory building where the fluxgate sensor and the standard Schonstedt magnetometer and its sensor were in the same stable environment. The drift was 1.6 to 1.8 gammas per degree centigrade, with an average value of 1.7 gammas and a standard deviation of 0.2 gamma per degree centigrade. The outputs of the magnetometers and temperature sensors were recorded on a strip chart.

Initial tests indicated a positive drift of the Y-channel of the fluxgate associated with a decrease in the temperature of the electronics package. Further testing will be performed at varying levels of the baseline. Since these tests are time consuming, an Apple II computer will be used to automate the process by providing simultaneous recording of all field components and temperature as a function of time. A complete temperature profile of the

fluxgate magnetometer will be obtained. A description of the computer and the programs completed thus far are included in Appendix I.

6. CONCLUSIONS

Support of the AFGL Magnetometer Network has involved repair, updating and calibration of instruments returned from the field stations. Work continues on the development of a computer-controlled three-component magnetic observatory. Investigation of the fluxgate magnetometer temperature characteristics and work towards minimizing the damaging effects of lightning on the induction-coil magnetometer will continue.

REFERENCES

1. Knecht, D.J., Hutchinson, R.O., and Tsacoyeanes, C.W., An Introduction to the AFGL Magnetometer Network, AFGL, Hanscom AFB, MA., April 1979.

2. Snare, R.C., A Geomagnetic Data Collection Network, AFCRL-TR-75-0593, AFGL-TR-0593, Hanscom AFB, MA., November 1975.

3. Devane, S.J., J.F., and Johnson, E.A., Investigation of Magnetic Field Phenomena in the Ionosphere, AFGL-TR-80-0099, AFGL, Hanscom AFB, MA., January 1980.

APPENDIX I. Microcomputer

The Apple II microcomputer purchased in September 1980, has the following peripherals and facilities:

1. Languages: Pascal, Fortran, integer BASIC, floating point BASIC, and assembly languages are available. Pascal and Fortran may interact and both may call assembly language routines.

2. Memory Storage: 64K bytes of memory are provided in the computer. The user-available memory is reduced by the needs of the language in use. There are two floppy disk drives which can each handle diskettes with 143K bytes of storage.

3. Input/Output: Operator interfaces are a keyboard and a nine-inch black and white CRT minitor. A modem directly attached to the phone lines allows use of the computer as either a "dumb" or "intelligent" terminal for use with a time-sharing computer such as the PDP/11 or VAX system at Boston College. The modem also allows our system to be accessed from an external terminal by phone lines. A parallel interface allows connection to many compatible I/O devices. An eight-bit combination A/D and D/A converter can read and output a voltage ranging from -5 to +5 volts.

4. Clock: A real-time clock with standby battery supply has been added. The clock provides, under program control, current date, hour, minute and second.

After testing the peripherals and facilities, some general purpose record and display programs were written. It soon became apparent that keeping programs as general as possible was the most efficient and productive way to produce lab-oriented software. General purpose recorder programs, written in a modular

fashion can be modified to fit a specific need. The Apple II U.C.S.D. Pascal language allows Fortran assembly language modules to be called into the body of the program, thus allowing a high degree of versatility and efficiency. The A/D program is written in assembly language to enhance speed. The Pascal language was chosen as the principal programming language because in Pascal one can write, debug and execute a program in one-third the time and with one-third the memory required for an equivalent BASIC program. Pascal allows a user to define complex data structures without being concerned with their implementation. One can define the fields of a record with appropriate names and types. Pascal's structured format permits problem solving in a natural manner. It forces the programmer to document steps logically, a procedure which may require more work at first, but makes the resulting program easier to read and modify. The only shortcoming we have encountered with our use of Pascal is that it lacks a method of examining the contents of a designated memory location as does the "PEEK" statement in BASIC. This, as well as speed considerations, is why an assembly language routine to read the A/D converter was written.

The following data program was written to display one of three sets of data acquired from a three-channel magnetometer. However, with only minor modification, it can be used to display one of up to sixteen floppy disk files of data from any -5v. to +5v. analog source.

```
PROGRAM RECALL

 ( *******************************)
 ( **This program calls to the****)
 ( **video display data stored in*)
 ( **one of three data files. ****)
 ( *******************************)

 USES APPLESTUFF, TURTLEGRAPHICS;

 TYPE COMP=PACKED RECORD
           XCOMP:  INTEGER;
           YCOMP:  INTEGER;
           END;

 VAR, G,H,I,J,K,L,M,N,P,Q
  X1, Y1, Z1: INTEGER
  X,Y,Z,
  BIASX, BIASY, BIASZ, U:REAL;
  FIELD:COMP;
  BS:FILE OF REAL;
  CF:FILE OF COMP;

 PROCEDURE SPACES(LINES:INTEGER);
      VAR I:INTEGER;

  BEGIN
    FOR I:=1 TO LINES DO
    WRITELN;
  END;

  PROCEDURE DELAY(SECONDS:INTEGER);
      VAR I:INTEGER;
  BEGIN
    FOR I:=1 TO SECONDS DO
    NOTE(0,163);
  END;
  PROCEDURE SETGRAPH;
  BEGIN
    INITTURTLE;
    GRAFMODE;
    PENCOLOR (NONE);
    MOVETO(0,961);

  END;
```

```
PROCEDURE INBIAS;
    VAR CHOICE:CHAR;
             I:INTEGER;
BEGIN
 RESET(BS,'OFFSET.DATA');
 GET(BS);
 BIASX:=BS ;
 GET(BS);
 BIASY:=BS ;
 GET(BS);
 BIASZ:=BS ;
 CLOSE(BS,LOCK);
END;

PROCEDURE SELECT;  (*SELECTS COMPONENT
                       TO BE DISPLAYED*)
    VAR CM,C:CHAR;

BEGIN
 REPEAT;
 REPEAT;
 WRITELN;WRITELN;WRITELN;
 WRITELN('        SELECT THE COMPONENT TO BE  ');
 WRITELN('        DISPLAYED BY ENTERING ITS' );
 WRITELN('        CORRESPONDING NUMBER.');
 WRITELN;WRITELN;
 WRITELN('           ENTER: ');
 WRITELN('                  1 FOR X');
 WRITELN('                  2 FOR Y');
 WRITELN('                  3 FOR Z');
 SPACES(10);
 READ(H);
 UNTIL (H=1) OR (H=2) OR (H=3);

             CASE H OF
                  1: CM:='X';
                  2: CM:='Y';
                  3: CM:='Z';
                END;

 SPACES(14);
 WRITELN('     ENTER STARTING MINUTE NUMBER');
 SPACES(10);
 READ(G);
 SPACES(12);
 WRITELN('          YOU HAVE SELECTED ' ,CM,'  AS THE');
 WRITELN;
 WRITELN('          COMPONENT TO BE DISPLAYED,AND');
 WRITELN;
 WRITELN('          ',G,' AS THE BEGINNING POINT.');
 SPACES(5);
 WRITELN('          ARE THESE PROPER?   Y OR N');
 SPACES(5);
 READLN;
 READ(C);
 UNTIL C='Y';
END;
```

```
PROCEDURE AXES(VSCALE:STRING);

BEGIN
 INITTURTLE;GRAFMODE;PENCOLOR(NONE);
 MOVETO(14,192);
 PENCOLOR(WHITE);
 MOVETO(14,14);
 MOVETO(279,14);
 PENCOLOR(NONE);
 MOVETO(0,183);
 WCHAR('+');
 WSTRING(VSCALE);
 MOVETO(0,101);
 WSTRING(' 0  - - - - - - - - - - - - - - - - - - - - - -  - - - - -');
 MOVETO(0,14);
 WCHAR('-');
 WSTRING(VSCALE);
 MOVETO(14,14);
END;

BEGIN                   (*MAIN BODY *)

  INBIAS;
  SELECT;         (*COMP.  TO DISPLAY*)
  U:=1.4;
  RESET(CF,'COMPFILE.DATA');
  SEEK(CF,G);
  SETGRAPH;       (* READY GRAPHICS *)
  AXES('50");
  PENCOLOR(WHITE);

  FOR P:=14 TO 279 DO BEGIN
    GET(CF);
    FIELD:=CF ;
                          (*PLOTS X Y OR Z*)
  X:=FIELD.XCOMP;
  Y:=FIELD.YCOMP;
  Z:=FIELD.ZCOMP;

  X1:=ROUND(X/U)+14;
  Y1:=ROUND(X/U)+14;
  Z1:=ROUND(X/U)+14;

      CASE H OF
           1:VPLOT:=X1;
           2:VPLOT:=Y1;
           3:VPLOT:=Z1;
         END;

   MOVETO(P,VPLOT);
 END;
CLOSE)CF,LOCK);
NOTE(40,60);
DELAY(5);
TEXTMODE;
END.
```

The following is an assembly language and machine language listing which reads the A/D convertor peripheral. The code is for the 6502 microprocessor used in the APPLE II.

```
MACHINE                              ASSEMBLY

0000:                                ;ZADCFILE
0000:                                .MACRO POP
0000:                                PLA
0000:                                STA %1
0000:                                PLA
0000:                                STA %1 + 1
0000:                                .ENDM
0000:


0000:                                .FUNC  ZADC,1   ;ONEWRD PAR

0000:
0000:                                POP 00000
0000: 68             #               PLA
0001: 85 00          #               STA 00000
0003: 68             #               PLA
0004: 85 01          #               STA 00000+1
0006: 68                             PLA
0007: 68                             PLA
0008: 68                             PLA
0009: 68                             PLA
000A:                                POP 00002
000A: 68             #               PLA
000B: 85 02          #               STA 00002
000D: 68             #               PLA
000E: 85 03          #               STA 00002+1
0010: A0 00                          LDY #0
0012: B9 02 00                       LDA 00002,Y
0015: AA                             TAX
0016: AD A1C0                        LDA 0C0A1
0019: A9 00                          LDA #0
001B: 48                             PHA
001C: EA                             NOP
001D: EA                             NOP
001E: EA                             NOP
001F: AD A1C0                        LDA 0C0A1
0022: 48                             PHA
0023: A5 01                          LDA 00001
0025: 48                             PHA
0026: A5 00                          LDA 00000
0028: 48                             PHA
0029: 60                             RTS
002A:                                 END
```

APPENDIX II. Contract Personnel

J. F. Devane, S.J.	Project Supervisor
E. A. Johnson	Project Engineer
Joy O'Malley	Secretary

APPENDIX III. Previous Contracts

AF19 (604) 3504	April 1, 1957 - March 31, 1959
AF19 (604) 5569	April 1, 1959 - Sept. 30, 1961
AF19 (628) 236	Oct. 1, 1961 - Oct. 31, 1964
AF19 (628) 4793	Nov. 1, 1964 - Oct. 31, 1967
F 19 (628)-68-C-0094	Nov. 1, 1967 - Oct. 31, 1970
F 19 (628)-68-C-0100	Nov. 1, 1967 - Oct. 31, 1970
F 19 (628)-71-C-0083	Nov. 1, 1970 - July 31, 1973
F 19 (628)-74-C-0003	Aug. 1, 1973 - June 30, 1976
F 19 (628)-76-C-0291	July 1, 1976 - Sept. 30, 1979